Introduction

The Big Picture

Soils are a thin layer, called the *pedosphere*, on top of most of Earth's land surfaces. This thin layer is a precious natural resource. Soils so deeply affect every other part of the ecosystem that they often are called the "great integrator." Soils hold nutrients and water for plants and animals. Water is filtered and cleansed as it flows through soils. Soils affect the chemistry of the water and the amount of water that returns to the atmosphere to form rain. The foods we eat and most of the materials we use for paper, buildings, and clothing are dependent on soils. Understanding soil is important for knowing where to build our houses, roads, buildings, and playgrounds as well. This investigation guides you through measurements of soil characteristics, soil moisture, infiltration, and soil temperature.

One of the most important characteristics of any soil is how much water it contains. Either in the form of a vapor or a liquid, water occupies about one-fourth of the volume of a productive soil. If the soil gets too dry and is not covered by vegetation, it blows away in the wind. Yet if there is too much water, the ground becomes soggy and cannot sustain many crops or, for that matter, the foundations of buildings. The rate at which water flows into or infiltrates the surface determines how much water will runoff during a rainstorm. Dry, porous soils can absorb large amounts of rain and protect us from flash floods. Soil that is nearly saturated with water or slow to take up water can heighten the likelihood of flooding.

All terrestrial life is directly or indirectly dependent on sufficient levels of water in the soil. Soil moisture combines with other properties of the land and climate to determine what kinds of vegetation grow. Soil acts as a sponge and holds water for uptake by the roots of plants. Some soils are more effective at this than others. For example, in deserts with sandy soil which does not hold water well, cacti store their own water, while other trees send roots deep in the soil to tap water buried tens of meters below the surface.

Soil temperature acts much the same way to influence all living organisms. Soil temperature changes more slowly than that of the atmosphere. In many temperate regions the surface soil freezes in winter, but below a certain depth, the ground never freezes and the temperature is almost constant throughout the year. In some cold climates, a permanent layer of ice called permafrost is found below the soil surface. Soil acts to insulate the deeper layers of soil and whatever lives in them from the extremes of temperature variation.

Figure SOIL-I-1

Soil Properties That Change Over Time		
Properties that change over minutes, hours, or days	*Properties that change over months or years*	*Properties that change over hundreds and thousands of years*
temperature moisture content composition of air in soil pores	soil pH soil color soil structure soil organic matter content soil fertility microorganisms density	kinds of minerals particle size distribution horizon formation

Both the temperature and moisture of the soil near the surface affect the atmosphere as heat and water vapor are exchanged between the land surface and the air. These affects are smaller than those of oceans, seas, and large lakes, but at times they significantly influence the weather. Hurricanes have been found to intensify instead of losing strength when they pass over ground that is already saturated with water. Meteorologists have found that their forecasts are sometimes improved if they factor soil conditions into their calculations. How surface soil temperature and moisture respond to changes in the atmosphere depends upon the characteristics of the surface of the soil and those of the underlying soil profile. In GLOBE, student measurements include many of the physical and chemical properties of soil which will provide insights into the role soil plays in climate.

Soil Composition and Formation

Soils are composed of three main ingredients: minerals of different sizes; organic materials from the remains of dead plants and animals; and open space that can be filled with water and air. A good soil for growing most plants should have about 45% minerals (with a mixture of sand, silt and clay), 5% organic matter, 25% air, and 25% water.

Soils are dynamic and change over time. Some properties, such as temperature and water content (a measure of soil moisture) change very quickly (over minutes and hours). Others, such as mineral transformations, occur very slowly over hundreds or thousands of years.

Soil formation (*pedogenesis*) and the properties of the soil are the result of five key factors. These factors are:

1. parent material – The material from which the soil is formed. Soil parent material could be bedrock, organic material, an old soil surface, or a deposit from water, wind, glaciers, volcanoes, or material moving down a slope.

2. climate – Heat, rain, ice, snow, wind, sunshine, and other environmental forces break down the parent material and affect how fast or slow soil processes go.

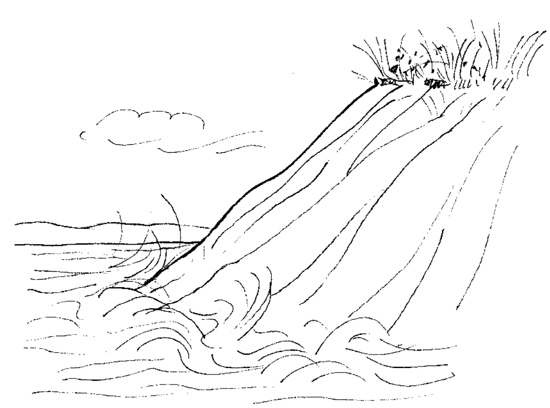
3. organisms – All plants and animals living in or on the soil (including micro-organisms and humans!). The amount of water and nutrients plants need affects the way soil forms. Animals living in the soil affect decomposition of waste materials and how soil materials will be moved around in the soil profile. The dead remains of plants and animals become *organic matter* which enriches the soil. The ways humans use soils affect soil formation.

4. topography – The location of a soil on a landscape can affect how the climatic processes impact it. Soils at the bottom of a hill will get more water than soils on the slopes, and soils on the slopes that directly face the sun will be drier than soils on slopes that do not.

5. time – All of the above factors assert themselves over time, often hundreds or thousands of years.

Soil Profiles

Due to the interaction of the five soil-forming factors, soils differ greatly. Each section of soil on a landscape has its own unique characteristics. The *face* of a soil, or the way it looks if you cut a section of it out of the ground, is called a *soil profile*, just like the profile of a person's face. When you learn to interpret it, the profile can tell you about the geology and climate history of the landscape over thousands of years, the archeological history of how humans used the soil, what the soil's properties are today, and the best way to use the soil. In a sense, each soil profile tells a story about the location where it is found.



To read some examples of these stories, see *Soils Around the World* at the end of this section.

Every soil profile is made up of layers called *soil horizons*. Soil horizons can be as thin as a few millimeters or thicker than a meter. You can identify the individual horizons because they will have different colors and different-shaped particles. They will feel different and have other properties that differ from those above or below them. Some soil horizons are the result of erosion. Soils are washed downstream and deposited over hundreds or thousands of years, creating extensive new layers of soil and gravel that can be identified in road cuts and trenches.

Soil scientists label horizons with a special code to identify them. Not all soils have the same horizons, and the horizons in your soil will depend on how it has formed. Some of the codes used to describe horizons are listed below:

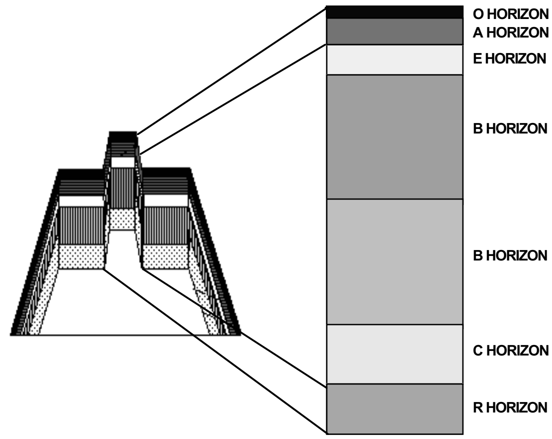
O Horizon

The O horizon is so named because it is made of *organic* material. This horizon is found on the soil surface and contains mostly organic material which has fallen from the vegetation above (such as leaves, logs, and twigs). It also includes the remains of animals and insects. Sometimes this organic material is decomposing so that it is difficult to recognize the leaves, twigs, or other material that were originally there. O horizons are most commonly found in forested areas. Agricultural fields, deserts, and grassy areas do not have O horizons in their soil profiles.

A Horizon

The A horizon is given its name because, like the first letter of the alphabet, it is the first mineral horizon of the soil and is commonly known as *topsoil*. The A horizon is made up mostly of mineral matter, although it may also include thoroughly decomposed organic material giving it a dark color. This horizon is usually darker than the horizon below it. In agricultural areas, the A horizon is the one that is tilled. When there has been much root decomposition and organic matter accumulation, the soil structure is granular. If compacted, the structure of the A horizon may be platy.

Figure SOIL-I-2



B Horizon

The B horizon is so named because it is generally the second major horizon in the profile, just as the letter B is the second letter of the alphabet. This horizon is primarily composed of parent material which has been severely weathered to the point that it is different in appearance. This horizon is commonly known as *subsoil*. Weathering causes changes in soil color, texture, and structure (which can be blocky or prismatic because of clay particles and chemical elements that move into the B horizon or columnar because of a high sodium content in dry regions). Also, the B horizon is called the accumulation (or *illuvial*) horizon because it is where the material leached from the A and E horizons has been deposited. Due to this accumulation, the B horizon may be rich in clays, organic matter, iron, aluminum, and other soil constituents that have moved in from above. Many B horizons have a reddish, yellowish brown, or tan color that is lighter than the A horizon. If the soil is saturated with water for long periods of time, the color may be gray or gray with red or orange streaks (mottles) through it.

Note: B Horizons may be very thick and may be broken down into two or more different layers. If there is more than one B horizon, they can be labeled as B1, B2, B3, etc. Look for changes in color, texture, structure, or consistence to help separate the B horizons from each other.

C Horizon

Like the letter C in the alphabet, the C horizon is usually the third major horizon in a soil profile. The C horizon is the most similar to the original parent material of the soil with no change in color, no structure formed (the soil is massive or single grained), no removal or deposition of soil materials through leaching, no coatings, no organic matter accumulation.

E Horizon

In certain soils (usually forested or under some wet conditions), an E horizon forms. The E horizon was named from the word *eluvial* meaning that clay, iron, aluminum, organic, and other minerals have been removed (leached) from it. It will appear white or lighter in color than the horizons above and below it. Many times, the soil structure is platy or single grained. This horizon is commonly found in forests where coniferous trees grow.

R Horizon

The R horizon represents a layer of rock that is sometimes found under the soil profile. The soil might have formed from this bedrock, or the soil parent material (such as *alluvial*, glacial or volcanic material) may have been deposited on top of the rock before the soil was formed.

Note: In a soil profile, you may not find all the horizons listed above in this table. For example, usually O and E horizons are found only in forested areas. If your soil profile is in an agricultural, desert, or grassy area, it will probably start with an A horizon and not have an E horizon at all. If the area has been eroded, your soil profile may start with a B horizon. Shallow soils, or soils that have not been extensively weathered may go from an A to a C horizon with no B horizon at all.

Your soil may have been altered by human activity at some time in the past. This could be a result of construction, when the builders placed soil *fill* from another location on this site, or when the horizons were not replaced in the same order as they were removed. Also, there may be more than one parent material from which your soil was formed. Parent material transported by water, wind, glaciers, volcanic activity, or landslides can be deposited on top of other parent material, or already existing soil profiles. This may become evident on the face of the soil profile by a sharp change in color, texture or other properties that indicate the soil did not all form from the same parent material.

Soils Around the World

The following figures illustrate a variety of soil profiles from around the world.

Figure SOIL-I-3: Grassland soils sampled in the southern part of Texas in the USA.

Figure SOIL-I-4: Soil formed under a forest in far eastern Russia, near the city of Magadan.

Figure SOIL-I-5: A tropical environment in Northern Queensland, Australia

Figure SOIL-I-6: Soil formed under a very cold climate near Inuvik in the Northwest Territory of Canada.

Figure SOIL-I-7: Soil formed under very dry or arid conditions in New Mexico, USA.

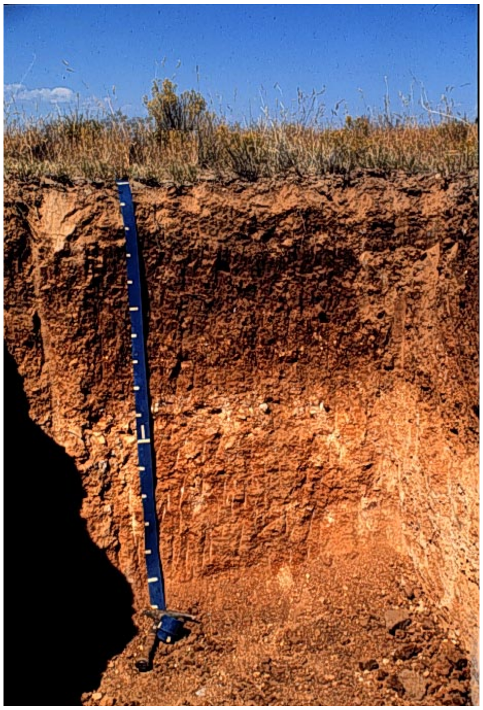


Figure SOIL-I-8: Wet soil sampled in Louisiana, USA

Dr. John Kimble and Sharon Waltman of the USDA Natural Resources Conservation Service, National Soil Survey Center, Lincoln, Nebraska provided the photographs shown here.

Overview of the Measurements

Soil Characterization

In the field, soil horizons can be distinguished from each other within a soil profile by differences in their structure, color, consistence, texture, and amount of free carbonates. When samples are taken back to the classroom or laboratory, measurements of soil characteristics such as bulk density, particle size distribution, pH, and soil fertility can also be different from one horizon to another.

Structure:

Structure refers to the natural shape of groups of soil particles or aggregates (*peds*) in the soil. The structure affects how big the spaces will be in the soil through which roots, air, and water may move.

Color:

The color of the soil changes depending on how much organic matter is present and the kinds of minerals it contains (such as iron which usually creates a red color, or calcium carbonate which colors the soil white in dry areas). Soil color also differs depending upon how wet or dry the soil sample is and can indicate if the soil has been saturated with water.

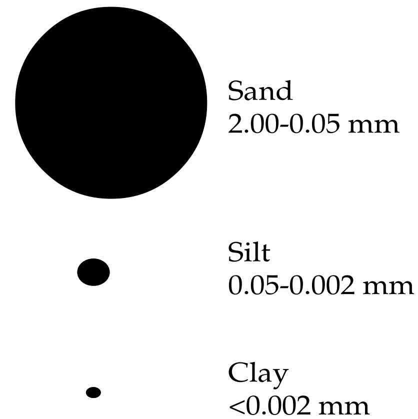
Consistence:

Consistence relates to the firmness of the individual *peds* and how easily they break apart. A soil with firm consistence will be harder for roots, shovels, or plows to move through than a soil with *friable* consistence.

Texture:

The texture is how the soil feels and is determined by the amount of sand, silt, and clay particles in the soil, each of which is a different size.

Human hands are sensitive to this difference in size of soil particles, so we are able to determine the texture or "feel" of the soil. Sand is the largest particle size group, and feels gritty to touch. Silt is the next size group, and feels smooth or *floury*. Clay is the smallest size group, and feels sticky and hard to squeeze. The actual amount of sand, silt, and clay size particles in a soil sample is called the *particle size distribution* and can be measured in the laboratory or classroom.



The relative (not the actual) size of sand, silt, and clay particles.

Figure SOIL-I-9

Carbonates:

Free carbonates are materials that coat soil particles in soils that are above pH 7, especially in arid or semi-arid climates. Carbonates usually have a white color, and can be scratched easily with a fingernail. They are salts of calcium or other elements that accumulate in areas where there is not extensive weathering from water. Also, carbonates can come from the parent material (e.g. limestone), can be caused by additions of carbonates to the soil, or can be the result of carbonate formation within the soil. Sometimes in dry climates, the carbonates can form a very hard and dense horizon which is similar to cement and will not allow plant roots to grow through it.

In GLOBE, this test is performed by squirting vinegar on the soil. If carbonates are present, there will be a chemical reaction between the vinegar, which is an acid, and the carbonates, which are bases, to produce carbon dioxide. When carbon dioxide is produced, it bubbles or *effervesces*. The more carbonates that are present, the more bubbles or *effervescence* you will observe.

Bulk Density:

Soil bulk density is a measurement of how tightly packed or dense the soil is. It is determined by measuring the weight of dry soil in a unit of volume (g/cm^3). How dense the soil sample is depends on the structure (shape) of the soil peds, how many spaces (pores) are in the sample, how tightly they are packed, and also the composition of the solid material. Soils made of minerals (sand, silt, and clay) will have a different bulk density than soils made of organic material. In general the bulk density of soils can range from 0.5 g/cm^3 in soils with many spaces, to as high as 2.0 g/cm^3 or greater in very compact horizons.

Knowing the bulk density of a soil is important for many reasons. Bulk density can give us information about the porosity (the proportion of the soil volume that is pore spaces) of a sample. This helps determine how much air or water can be stored or moved through the soil. Bulk density also indicates how tightly soil particles are packed together and if it will be difficult or easy for roots to grow or shovels to penetrate into and through a soil horizon. Bulk density is also used in converting between weight and volume for a soil sample. If we know the weight of a soil sample, we can calculate its volume by dividing the sample weight by the bulk density of the soil. If we know the volume of a soil sample, we can determine its weight by multiplying the sample volume by the bulk density of the soil.

Particle Size Distribution:

The amount of each particle size group (sand, silt, or clay) in the soil is called the soil particle-size distribution. Knowing the particle size distribution of a soil sample helps us understand many soil properties including how much water, heat, and nutrients the soil will hold, how fast water and heat will move through the soil, and what kind of structure and consistence will form.

The distribution of sand, silt, and clay in your sample will be determined by a settling measurement using an instrument called a *hydrometer*. The hydrometer is used to measure the amount of soil that stays in suspension after some of the soil has settled to the bottom of the cylinder.

Sand is the largest soil particle size group, silt is intermediate in size, and clay is the smallest. See Figure SOIL-I-9. There is disagreement in the scientific community about the exact size ranges used to distinguish sand from silt. For GLOBE, we will be measuring sand and silt based on 2 different size definitions:

1. The US Department of Agriculture (USDA) defines the size of sand as 2.0 - 0.05 mm, and the size of silt as 0.05 - 0.002 mm.
2. The International Soil Science Society (ISSS) defines the size of sand as 2.0 - 0.02 mm, and the size of silt as 0.02 - 0.002 mm.

GLOBE students will find the silt and sand amounts for both of these definitions so that our data can be used by scientists world wide.

Clays are the smallest particle size group and are defined by both organizations as being smaller than 0.002 mm. Particles greater than 2 mm are called stones or gravels and are not considered to be soil material.

Heavy, large particles settle first, so when a soil sample is stirred or shaken in a 500 mL cylinder, sand particles (according to the USDA definition) settle to the bottom of the cylinder after 2 minutes, while the clay and silt size particles stay in suspension. After 12 minutes, the sand (according to the ISSS definition) has settled, leaving the clay and silt particles in suspension. After 24 hours, the silt particles have settled, leaving only the clay in suspension.

pH:

The pH of a soil horizon (how acidic or basic the soil is) can be measured in the laboratory or classroom. The pH influences what can grow in the soil and is the product of the kind of parent material, the chemical nature of the rain and other water entering the soil, land management practices, and the activities of organisms (plants, animals, fungi, protists, and monera) living in the soil. For example, needles from pine trees are high in acids, and as they decay over time, they lower the pH of the soil. Soil pH is an indication of its chemistry and fertility. Just like the pH of water, the pH of soil is on the same logarithmic scale (see the *Introduction* of the *Hydrology Investigation* for a description of pH). It is important to know the pH of the soil because it affects the activity of the chemical elements in the soil, and so affects many soil properties. Different plants grow best at different pH values. Farmers will add *amendments* like calcium carbonate or calcium sulfate to change the pH of the soil depending on the kind of plants they want to grow. The pH of the soil also may affect the pH of ground water or of a nearby water body such as a stream or lake.

Fertility:

The fertility of a soil is determined by how many nutrients it has stored. Nitrogen (N) in the form of nitrate, phosphorus (P), and potassium (K) are three soil nutrients important for the growth of plants, and need to be maintained in the soil at a suitable level. Each also has the potential to leach from the soil into groundwater. By testing the soil for N, P, and K, we can determine how much of each is present in the soil horizons at your sample sites. Soil fertility information can help to explain why and how well certain plants grow at a Soil Characterization Sample Site, and also can be related to the water chemistry you will be measuring in the *Hydrology Investigation*.

Sampling Strategy

The protocols for Soil Characterization should be done once at each site where soil affects another GLOBE measurement. The two highest priority sites are within the Biology Study Site and the Soil Moisture Study Site. The protocols are divided between field and classroom activities. In the field, students describe and sample soil. For this, a hole is dug either with a shovel or an auger. Obtaining a soil profile one meter deep is desired, but an option is provided to sample the top 10 cm of soil when obtaining a 1 m profile is not possible. All students will describe the soil, take samples back to the classroom, dry and sieve the samples, determine the bulk density, and measure them for pH, nitrate, phosphorus, and potassium (N, P, K), and soil particle-size distribution. A measurement of surface infiltration rate should be taken as well.

Soil Moisture

Students should measure soil moisture at least twelve times every year at regular intervals. The choice of whether to take weekly measurements for 12 weeks, monthly measurements throughout the year, or 12 measurements at intervals of two or three weeks is left to GLOBE teachers and students. Different sampling patterns will provide data that are used by scientists in different ways and will show students different aspects of the variations in soil conditions. Measurements will be more interesting to students if they observe significant changes. Generally, soil moisture conditions will change most rapidly in early summer or during the transitions between the wet and dry seasons. Teachers and students should choose a sampling strategy which works well in the context of their school and which will result in 12 measurements being taken.

Any one of three sampling strategies can be chosen to match the capabilities of the students and the situation in your school. Again, different sampling strategies will produce data that will be used in different ways and will illustrate different aspects of soil moisture variation. A simple drying and weighing procedure is used to determine the soil water content of the soil samples in all three strategies.

In the easiest strategy, students sample soils near the surface at 0 - 5 cm, which is as deep as soil-moisture sensors on satellites penetrate the ground, and at 10 cm. Three samples are taken at each depth to provide a good check on data quality for a single location. In a second strategy, students take samples of the soil from a depth of 0 - 5 cm, every 5 m along a 50 m transect. This provides good information on local variations and a better characterization of an extended area. Three samples are taken at one location along the transect to check data quality. With both these sampling strategies, since students and satellites observe soil moisture near the surface, the two sets of measurements can be compared. The GLOBE data can be used to help calibrate, validate, or interpret the data from satellite sensors or aircraft versions of them. In a final strategy, samples are collected at five depths —

0-5, 10, 30, 60, and 90 cm. This strategy provides insight on how water moves through the soil column and provides data that better relate to the uptake of water by plants.

Students collect their soil moisture samples, place them in labeled soil sample containers and weigh them. Then, the samples are dried in a low-temperature oven (75 - 105 C) until all water is removed and the samples are weighed again. The difference in the weights before and after drying equals the amount of water that was in the soil. Scientists call this the *gravimetric* technique, which means a measurement by weight. The ratio of the weight of the water to the weight of the dry soil is called the *soil water content*. Note that this is not a percentage, since you do not divide by the total wet weight. The dry weight is an indication of the size of the soil sample. It is used because bulk density is usually a constant characteristic of a soil. When you divide the weight of the water by the dry soil weight, you get a number (soil water content) which can be compared with your measurements on other days even though the size of the soil samples may vary from one day to the next.

Soil water content typically ranges between 0.05 and 0.40 g/g. Often these values are multiplied by 100, and that is the convention we ask GLOBE students to follow. Even desert soils retain a small amount of water, although surface soils can fall below 0.05 g/g. Organic-rich soils, peat, and some clays can absorb large amounts of water, so it is possible to measure values above 0.40 g/g.

Infiltration

Infiltration, the rate water flows into the ground, is an important hydrologic property of soil. Scientists need this information to predict and model how much precipitation runs off or is stored by the soil. Infiltration rate depends upon many factors: soil structure, soil texture, bulk density, soil water content, and organic matter in the soil. Infiltration rates vary from less than 20 mm/hr for clays and compacted soil to 60 mm/min for loose, dry sand.

Infiltration should be measured at least three times each year at your Soil Moisture Study Site and once at each Soil Characterization Sample Site. A simple device called a double ring infiltrometer, made from two concentric cans of different diameters, will be used. Because infiltration varies with soil moisture, which changes with time, students will make one to nine measurements of infiltration over a 45 minute period. These observations should be taken on days when students are also taking soil moisture samples. Because infiltration rate can change by orders of magnitude due to animal or plant disturbances, students will take measurements of infiltration on a given day at each of three locations within 2 meters of one another.

Soil Temperature

Soil temperature measurements are related to the maximum and minimum daily temperatures measured in the *Atmosphere Investigation*. Students should gain useful insights by comparing the air temperatures with these observations as well as with the surface water temperature and precipitation measurements.

Soil temperature is measured at the Soil Moisture Study Site which should be within 100 m of the Atmosphere Study Site. If your school is not taking soil moisture measurements, take soil temperature measurements within 10 m of the Atmosphere Study Site. Measurements are taken at depths of 5 cm and 10 cm and provide data directly related to the measurement of near-surface soil water content at the site. Soil temperature should be measured weekly throughout the year. In addition, every three months on two consecutive days, students should take measurements at roughly two hour intervals throughout the day to reveal how near surface soil temperature varies with time of day at the study site.

Preparing for the Field

Soil Moisture Sampling Strategies and Site Layout

All Soil Moisture Study Sites should be located in the open, away from buildings, overhanging trees, and roads. The sites should not be irrigated. It is highly desirable that the Soil Moisture and Atmosphere Study Sites be within 100 m of one another so that their data can be interrelated and combined to obtain a more comprehensive picture of the environment near each GLOBE school.

The layouts for the three sampling strategies to be used in soil moisture measurement are summarized in the following sections.

The Star

Students collect soil-moisture samples at two depths close to the surface. Over the 12 different measurement days, the samples will be taken in a star pattern with a two meter diameter.

The Transect

Students collect eleven soil samples along a transect. These measurements are particularly helpful for comparison with satellite imagery. The transect is a straight line 50 meters long across an open area. Students measure soil moisture every five meters along this line. At one location along the transect, three samples are taken within 25 cm of one another to assist in checking data quality.

Depth Profile

Students take soil moisture measurements from samples cored out of the ground at five different depths — 0-5, 10, 30, 60, and 90 cm — using an auger.

An *Optional Gypsum Block Soil Moisture Protocol* for measuring soil water content, that is only recommended for advanced students, is given as well. Gypsum blocks are placed in the soil at four depths — 10, 30, 60, and 90 cm. — and students electronically monitor the moisture in the gypsum by determining how well the blocks conduct electricity. These measurements can be most directly related to the *Atmosphere Investigation* observations as they are taken daily. The gravimetric technique for determining soil moisture is used in conjunction with this optional protocol to calibrate the gypsum block readings.

Integrating with Other GLOBE Investigations

This investigation introduces students to rich connections between the soil and the surrounding land, water, and atmosphere. Placing your data collection stations in close proximity to each other will help you study interactions between the observed parameters. Some interesting comparisons are possible when you:

- locate a Soil Characterization Sample Site at the Land Cover/Biology or Soil Moisture Study Sites or at Quantitative Land Cover Sample Sites;
- do the introductory Hydrology activities along with the soil characterization and soil moisture activities; and
- take the soil moisture measurements near the Atmosphere Study Site.

Time Considerations

Spring and fall are usually the best times to study soil moisture near the surface or in depth profiles because the ground is less likely to be frozen or too dry. The activities should be done when students can observe the greatest contrasts.

The day after a rain is ideal for taking a soil moisture walk to observe ponded water, moisture under ground litter, dry and sunny spots, muddy depressions, and the soil beneath a canopy of trees or shrubs.

Educational Activities

Student Learning Goals

The soil system provides a natural laboratory for integrating many science activities. Students will develop an understanding of soil science, geology, biology, and ecology by studying the origin of their soil profile, the profiles of other soils, and how soils are affected over time by climate, vegetation type, parent material, and land use.

Students will understand the role of heat, water, and chemical constituents during soil formation (pedogenesis) and on the soil within their study site. Activities in these areas will provide a natural background for studying chemistry and physics.

Students will learn about soil moisture and temperature and their importance in local and global hydrologic, carbon, and energy cycles. The challenges of using remote sensing to observe the way soils affect regional and global processes will be introduced. Modeling techniques to predict soil properties and ecosystem parameters will also be included.

Students will develop observational skills by identifying soil properties and learning to identify how the interaction of climate, topography, biology, parent material (geology), and time form different types of soils. They will enhance their field skills in taking measurements properly, handling samples, and taking notes.

Students will become familiar with terminology, nomenclature, and methods that scientists use so that students and scientists can communicate with each other.

In addition, students will learn chemistry, physics, and biology concepts, and use math to visualize and model soil and related water properties and processes. Statistics and graphing will also be important to analyze findings.

Student Assessment

To assess your students' learning over the course of this investigation, we recommend that you evaluate students based on their:

Critical Thinking Skills

- Clear understanding and comprehension of concepts: Challenge their comprehension by presenting them with other possible scientific issues for inquiry. How well do they formulate questions, hypotheses, and methodologies to study their problems? Are their interpretations and conclusions thoughtful? In addition, are they critically reviewing information by challenging statements made by scientists, other students, and the teacher? They should be encouraged to question and ask for statements to be clearly explained. This will help create a real scientific community within the classroom that respects everyone's opinions and concerns.
- Observations and record keeping: Accuracy is essential for validation of research. Student observations should take into consideration issues that can compromise data such as sloppy methodology, inadequate sampling, and imprecise record keeping. However, mistakes are part of science. Students must understand that mistakes must be acknowledged in order to correct them. Even when results do not seem to be accurate, it is important that they are reported. Sometimes, even seeing nothing is an important observation. Making up data is lying and will only grow into a bigger problem later.
- Organization of scientific data: Questions at issue should be presented clearly, and pursuit of research and data must be organized to support these questions. Students must be able to judge what is adequate methodology to use in pursuing answers. Students must be able to interpret data to ensure the soundness of their conclusions.

Communication Skills

The purpose of context-based learning is to introduce students to real life situations. Such an approach stresses the importance of communicating with others. Students should be able to communicate information, both verbal and written, in informal and formal settings. Informal settings of the classroom are used to hone their critical thinking skills and their ability to work cooperatively on common goals. Students should be able to work cooperatively with their peers to improve the quality of their investigations. They should be able (at the intermediate and advanced levels) to develop group assignments and tasks directed at achieving the goals of their investigations. This should be evident through conversation and written materials such as group discussions, GLOBE Science Notebooks, or weekly work reports.

Formal expressions of their knowledge through oral presentations and final reports need to be encouraged. These presentations and reports should inform listeners or readers comprehensively of the study in which the student participated. Students should be able to concisely express this information as scientists do at symposiums and in professional journals. Students also should be familiar, comfortable, and able to use the new scientific terminology they are learning. In this way, they will be better able to understand scientific literature and communicate precisely.

Learning to communicate in both formal and informal manners are not only essential science skills but will enable students to function better in adult life. They must be able to express themselves in a comprehensible manner to both their peers and the community.

To assess your students' learning over the course of this investigation, we recommend that you evaluate students based on their GLOBE Science Notebooks, presentations and reports, organization, understanding of concepts, measurement skill, data analysis and presentation, and soundness of conclusions.